Assumptions and Definitions

A number of parameters are used to interpret the energy footprints. These are defined below, in the order they generally appear.

Primary energy use – the total processing energy consumption associated with an industrial sector. It is the sum of energy purchases (fuel and electricity), byproduct energy produced onsite, and the offsite losses associated with energy purchased from utilities and fuel suppliers (see offsite losses, below). Primary energy does not include feedstock energy, i.e., energy used as a raw material.

Offsite losses – the energy losses incurred during the generation and transmission of electricity at offsite utilities, plus the energy losses incurred during the transport of fuels to the plant boundary. The efficiency of utility power generation and transmission is assumed to be 10,500 Btu/kWh, which is equal to an overall efficiency of about 32.5%. This does not represent the state-of-the-art, but an average value for the national grid. Fuel transport energy losses are assumed to be about 3%.

Fuel and electricity use – direct use of fuels and electricity at the plant site, taken directly from the Manufacturing Energy Consumption Survey [MECS 1998] for the manufacturing sector, and estimated for mining based on a recent study [Mining 2002]. Electricity includes purchased electricity only, not electricity generated onsite (see electricity demand, below). Fuels used to generate on-site electricity as well as byproduct fuels are included in the fuels category. Offsite electricity losses are not included.

Energy export – excess energy (mostly electricity) that is generated onsite and exported offsite to the local grid or another facility.

Electricity demand – the net use of electricity at the plant site, including purchased electricity and electricity generated onsite, minus electricity exported offsite.

Energy distribution systems – pipes and transmission lines for delivering fuels, steam and electricity to processes and equipment.

Energy conversion systems – systems that convert energy into usable work for delivery to processes, such as heat exchangers, fired heaters, condensers, heat pumps, machine-drive and onsite transportation.

Process energy – energy used in industry-specific processes, such as chemical reactors, steel furnaces, glass melters, casting, welding or forging of parts, concentrators, distillation columns, and so forth.

Onsite losses – losses that are incurred in energy distribution and conversion systems, and in the central energy plant where steam and electricity are generated. Specific loss factors are shown in Table 2.

Boiler losses represent energy lost due to boiler inefficiency. In practice, boiler efficiency can be as low as 55-60%, or as high as 90%. The age of the boiler, maintenance practices, and fuel type are factors. Power generation losses vary depending on whether cogeneration is employed (systems producing both steam and electricity). It is assumed that the greater losses are in steam pipes (20%), with small losses incurred in other fuel transmission lines (3%) and electricity

transmission lines (3%). Losses in steam pipes and traps have been reported to be as high as from 20 to 40% [PNNL 1999]. For conservatism, a value of 20% was used for steam distribution losses.

As shown in Table 2, onsite power generation losses are assumed to be about 45%, which represents a relatively state-of-the-art gas turbine with heat recovery. Cogeneration raises the thermal efficiency of the power generating system by as much as 25-35%, significantly reducing power losses [ADL 2000].

Distribution losses represent steam heat lost in traps, valves, and steam pipes, and transmission losses in onsite fuel and electricity lines. In practice, these losses are very site-specific, and depend largely on plant size and configuration. The loss factors shown in Table 2 may underreport these losses, which have been reported to be as high as 10-40%. Sources are given in the Reference section. For simplicity, in this analysis distribution losses are distributed among the largest end-use categories.

Energy conversion losses occur in heat exchangers, preheat systems, or other equipment where the transfer of energy from steam or other direct heat or cooling takes place, prior to delivery of energy to the process. Losses also occur in electrolytic cells, and other energy systems such as onsite vehicles or other transport systems. In many cases energy conversion equipment is directly integrated with the process unit, making it difficult or impossible to estimate pre-process losses. As a result, the estimates for losses shown here may overlap with actual process losses, which are not estimated. Motor losses represent losses in motor windings as well as mechanical losses in the motor-driven systems (e.g., compressor) that occur during the conversion of energy to useful work.

Table 2. Loss Factors for Selected Equipment

Energy System	Percent Energy Lost
Steam systems	Boilers – 20% Steam pipes and traps - 20% Steam delivery/heat exchangers – 15%
Power generation	Combined heat and power – 24% (4500 Btu/kWh) Conventional power – 45% (6200 Btu/kWh)
Energy distribution	Fuel and electricity distribution lines and pipes (not steam) – 3%
Energy conversion	Process heaters – 15% Cooling systems – 10% Onsite transport systems – 50% Electrolytic cells – 15% Other – 10%
Motor systems	Pumps – 40% Fans – 40% Compressed air – 80% Refrigeration – 5% Materials handling – 5% Materials processing (grinders) – 90% Motor windings – 5%

Combined heat and power (CHP) – energy system used for onsite cogeneration of steam and electricity.

Conventional power – gas or steam turbines generating onsite power, with heat recovery.

Steam systems – the complete steam system, including boilers, steam distribution lines, steam traps, and final delivery of steam to the process (e.g., heat exchangers).

Fired Heaters – direct and indirect-fired heaters such as furnaces, dryers, re-boilers, and evaporators.

Process heating – an aggregate of the energy used for process heating, including the use of steam, fired heaters, and all other heating devices.

Process cooling – energy used for cryogenic and other cooling systems. This category may have some overlap with motor-drive refrigeration.
Electrochemical or Electrolytic Cells – Energy used in systems that convert raw inputs to products through an electrochemical reaction

Motor systems – motor-driven systems, such as compressors, fans, pumps, materials handling and processing equipment, and refrigeration. Materials handling equipment typically includes conveyors and assembly processes that are motorized. Materials processing includes grinders, crushers, mixers, and other similar equipment of this nature. Motor energy is converted to external work (rotating, lifting, spinning, moving), and is sometimes called shaft work.

Onsite Transport – Energy used to fuel equipment (trucks, forklifts, etc.) that carry materials between locations at the plant site.

Facilities – energy used to provide heat, cooling, and lighting for building envelopes at the plant site.